Artificial Recharge via Injection Wells for Salinity Ingress Control of Salalah plain aquifer, Oman

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Overview

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- The Problem
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Introduction

The Problem:

- Increased extraction of groundwater and reduction of flow towards the coast of Salalah has caused the saltwater interface to move inland.
- Due to permeable aquifer conditions, well injection was preferred, and the injection scheme had started in April 2003 (Shammas, 2008).

Objectives of the study:

- To study the effectiveness of the artificial groundwater recharge by MTEs on halting SWI in the Salalah coastal aquifer.
- To determine and compare the results of the predictive modeling scenario conducted in 2008 by the author is in harmony with the results of the current actual transient scenario for the same period of years 2006-2020.

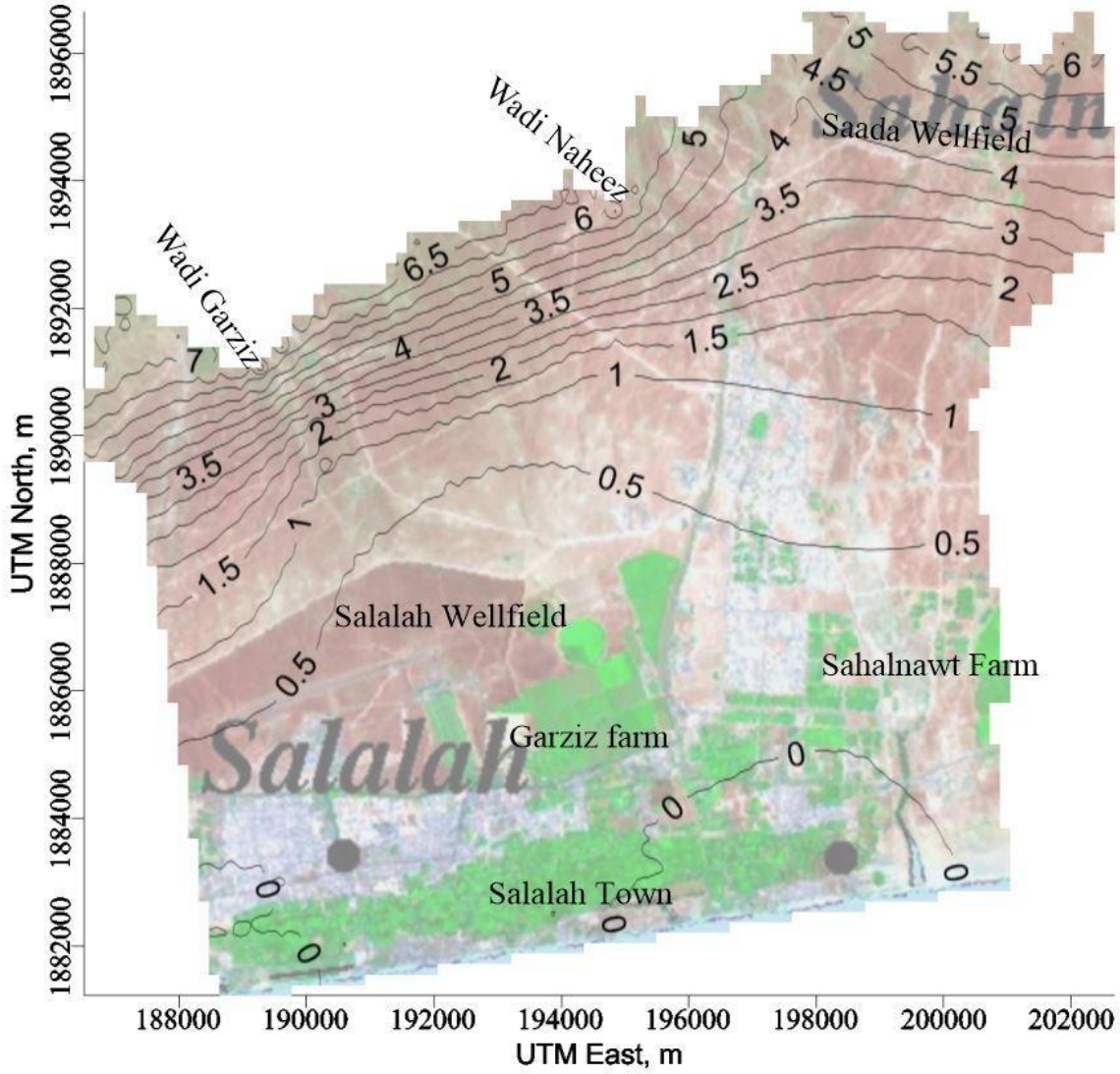
Materials and Method

- A modeling scheme of 3D flow groundwater simulation model using MODFLOW (McDonald and Harbaugh 1988) was utilized in this study under constant underflow.
- Solute transport predictive modeling was carried out in Salalah plain aquifer using MT3DMS (Zheng and Wang 1999) under constant underflow representing a mass transport simulation model and PMPATH was used for the advection transport.
- Predictive simulation and current actual transient simulation of the aquifer were carried out for the 2006-2020 years under constant underflow to predict the behavior of the aquifer under the injecting MTEs method.
- The baseline scenario assumes that underflow is constant through the predictive and current actual transient period.

Results and Discussions

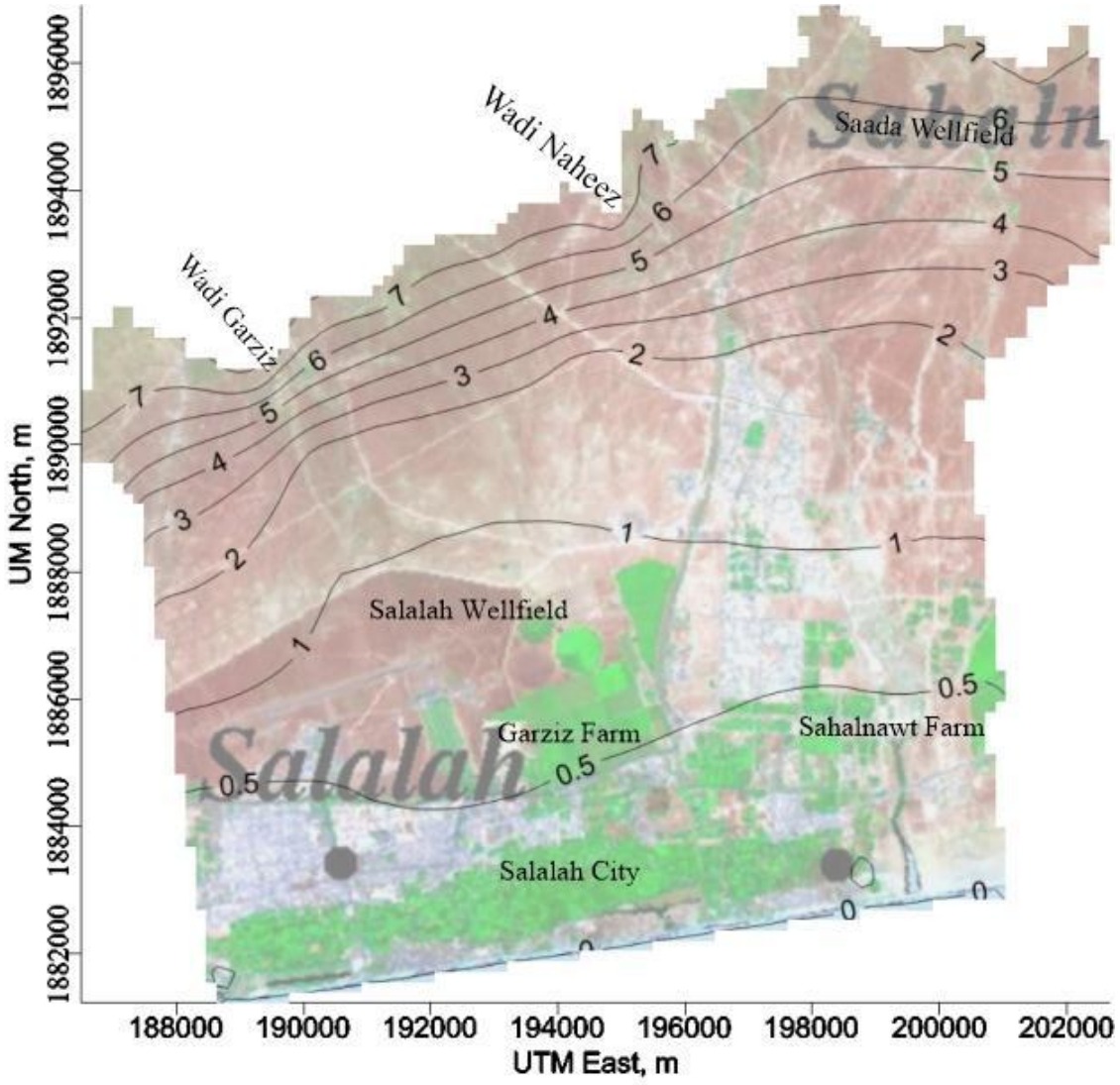
Potentiometric heads result under constant underflow

- This figure shows the water levels in 2020 during the predictive transient. Figure 11 explains that the water levels at 0.5 m amsl reached areas far inland behind Salalah well field areas at approx. 8 km inland.
- The water levels at the center of the coastal agriculture strip are less than 0.05 m amsl. At the east and west of the coastal agricultural strip, the water levels were recorded at 0 m amsl.
- Fig 11. The schematic diagram of water levels (m) period 28- year 2020 with injection, Predictive scenario.



Results and Discussions

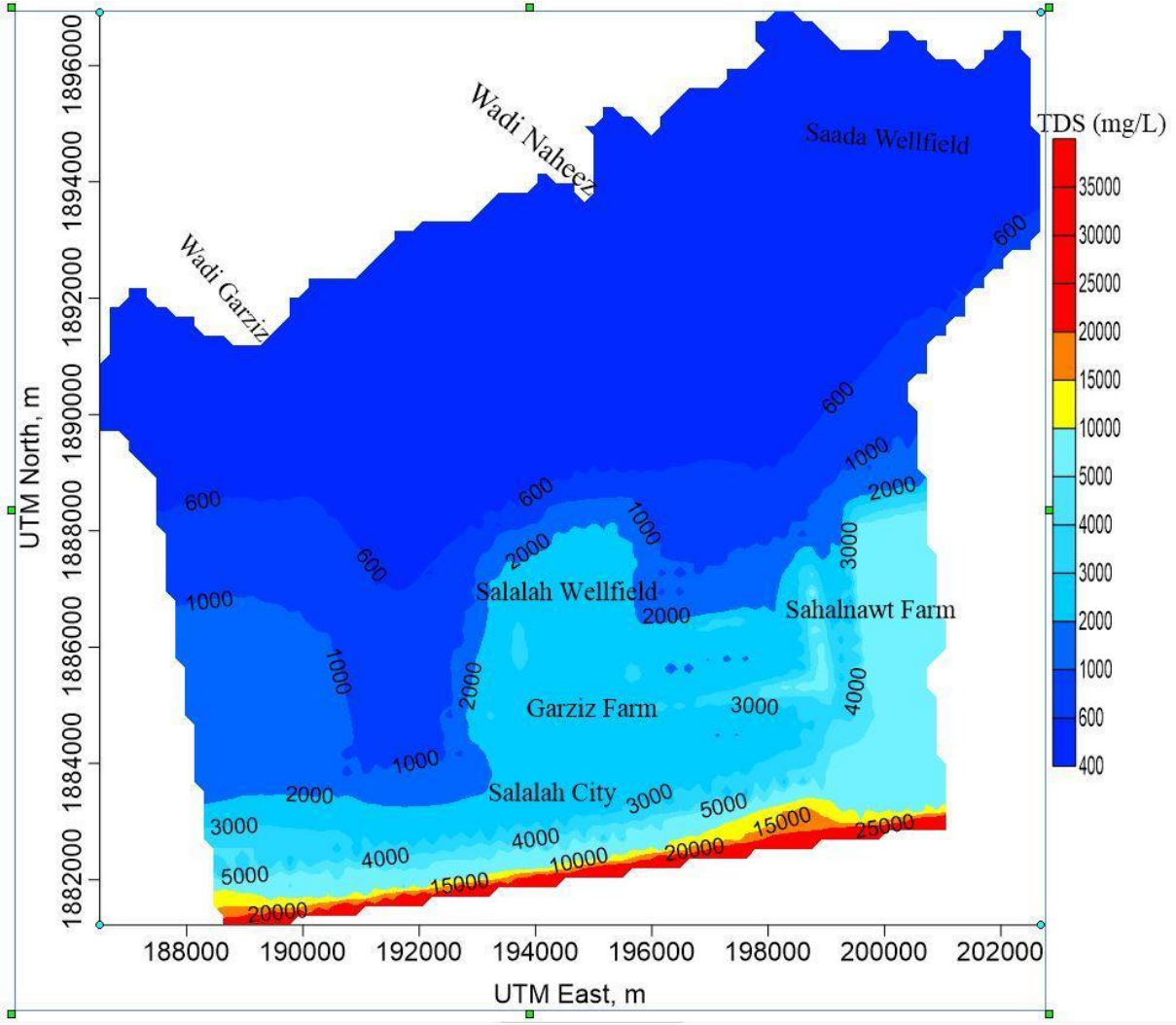
- The water levels in 2020 during the current transient period have been taken too and compared as shown in Figure 12 where the water levels at 0.5 m amsl reached the areas under Garziz farm site, at approx. 4 km inland. The water levels at the center of the coastal agriculture strip are less than 0.5 m amsl. At the east and west of the coastal agricultural strip, the water levels were recorded at 0.02 m amsl.
- To compare the predictive scenario with the current transient scenario in this periodic modeling, it was revealed that the results of water levels had increased in the current transient scenario as compared with the predictive scenario during the same period. The comparison has been elicited by means of groundwater pumping reduction from Salalah well field and Garziz farm.
- Fig 12. The schematic diagram of water levels (m) with injection at the year 2020, current transient scenario.



Results and Discussions

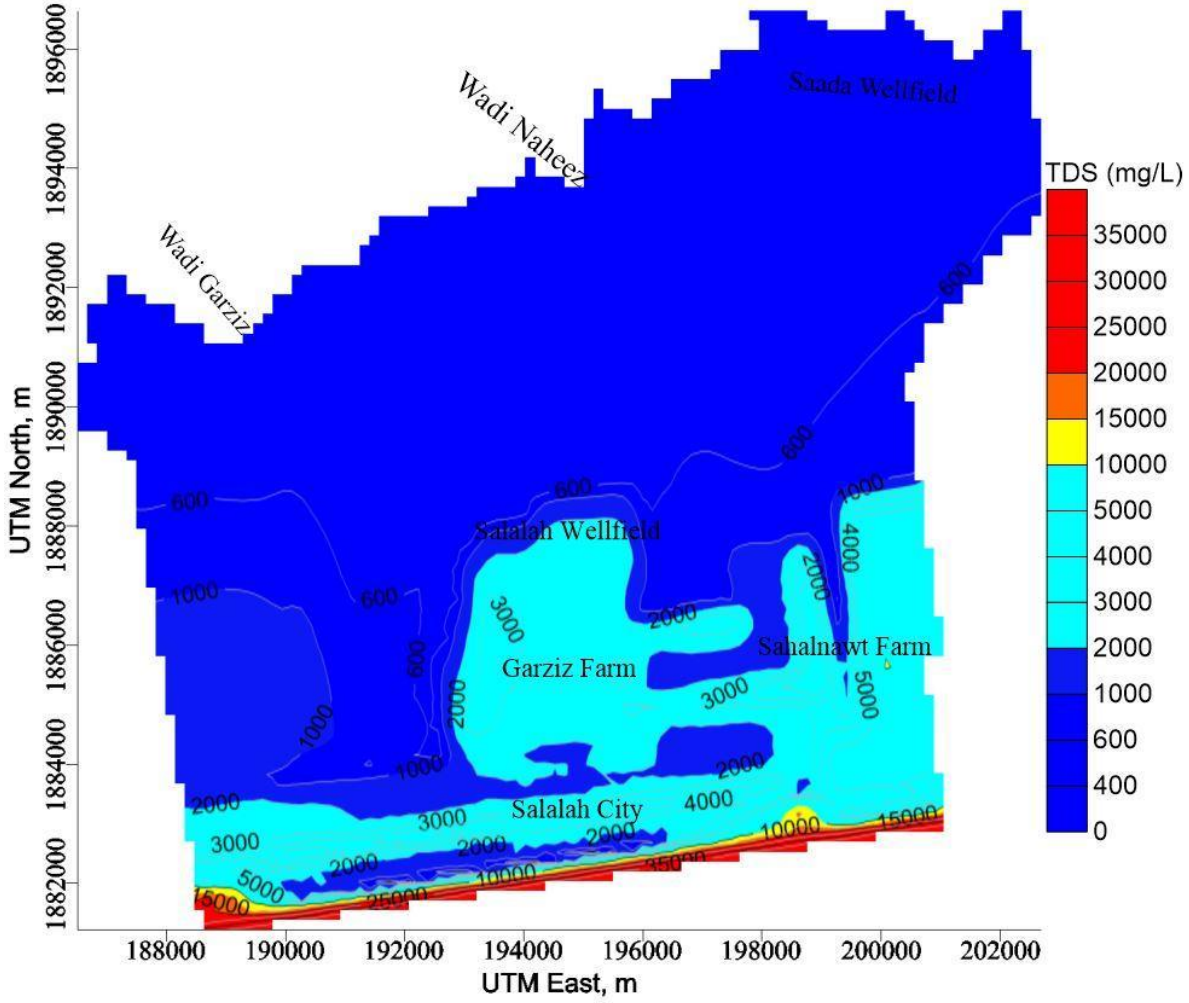
Solute transport results under constant underflow

- The salinity levels (TDS, mg/L) in Figure 19 located at the center of the coastal agricultural strip (Salalah city) is within 3000 mg/L while along the eastern and western parts, the TDS exceeded 4000 mg/L. Seawater intrusion is obvious and TDS exceeded 10000 mg/L at most of the areas inland at distances 500 m from the shoreline. This figure shows that the TDS levels reached 3000 mg/L at areas along the injection route lines which is located at 1.5 km from the shoreline, which means that the injection by MTEs pushes back the saline intrusion.
- Fig 19. The schematic diagram of TDS (mg/L) with injection in the year 2020, Predictive scenario.



Results and Discussions

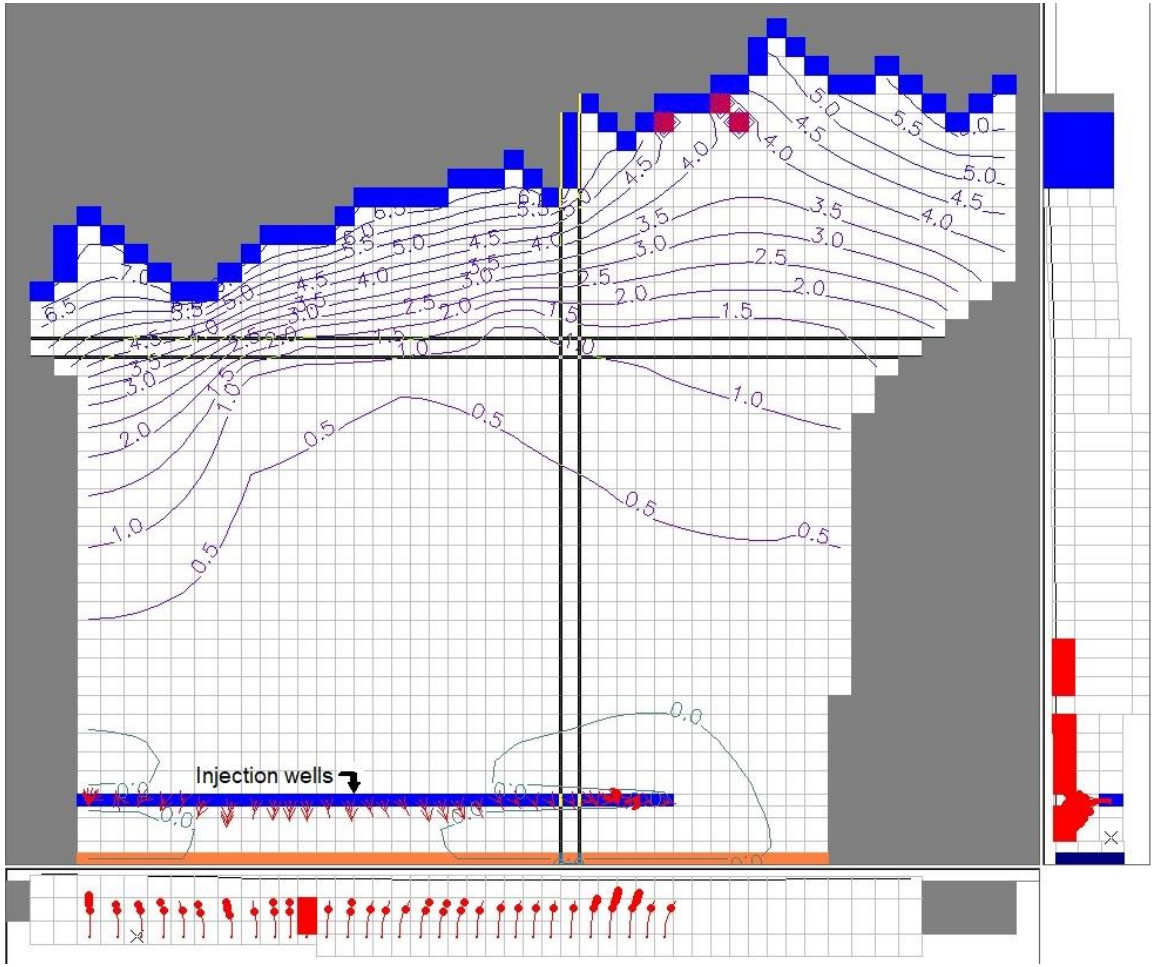
- In Figure 20, the salinity levels (TDS, mg/L) located at the center of the coastal agricultural strip (Salalah city) is within 2000 mg/L whereas, at east and west parts of this strip, the TDS exceeded 3000 mg/L. Seawater intrusion is obvious and TDS exceeded 10000 mg/L at most of the areas at distances 500 m from the shoreline. This figure shows that the TDS levels reached 2000 mg/L at areas along the injection route lines which is located at 1.5 km from the shoreline, which means that the injection by MTEs pushes back the saline intrusion.
- To compare the predictive scenario with the current transient scenario at this period, the solute transport levels show that salinity results were decreased in the current transient scenario as compared with the predictive scenario during the same period as a result of groundwater pumping reduction from the Salalah well field and Garziz farm.
- Fig 20. The schematic diagram of TDS (mg/L) with injection in 2020, current transient scenario.



Results and Discussions

Advection transport results under constant underflow

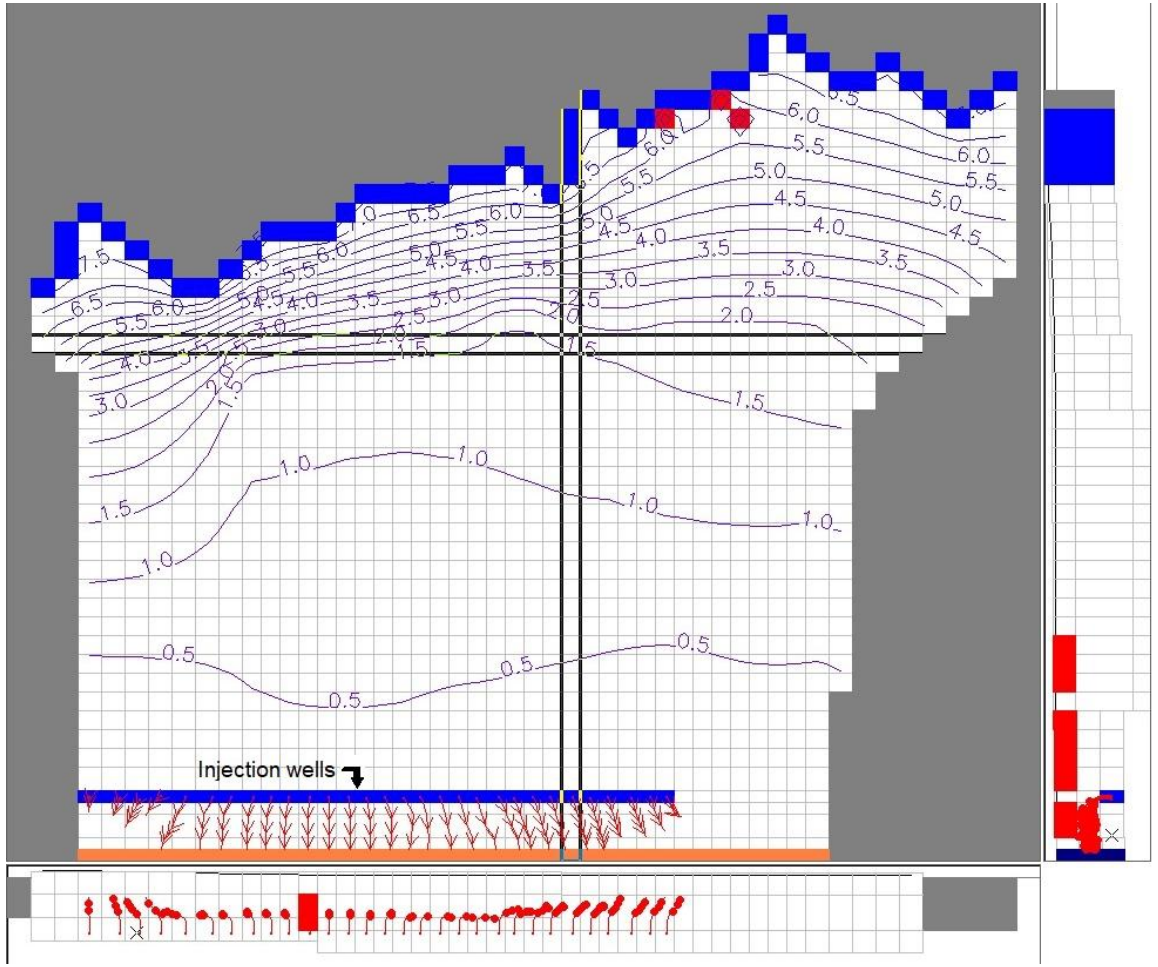
- Figure 21 shows the effectiveness of the injection method in combating SWI in 2020 under predictive scenario as revealed with no-management interference compared to Figure 22 under a current transient scenario with management interference. In Figure 21, the solute transport of the injected MTEs could travel almost 500 m downstream in just one year by using PMPATH (advection transport) compared to the current transient scenario (figure 22), where the path lines could travel more than 1.2 km downstream of the injection lines in about one year.
- Fig 21. PMPATH results of one-year simulation time, with the injection in 2020, predictive scenario.



Results and Discussions

Advection transport results under constant underflow

- Fig 22. PMPATH results of one-year simulation time, with the injection in 2020, current transient scenario



Conclusion and Recommendations

- The injection scheme of the MTEs in the Salalah plain aquifer stabilized the water levels and reduced the salinity (TDS) along the injection lines.
- The abstraction from the aquifer has been able to manage about 77% of pumping rates of the wells that are operating at Garziz farm considerably blocked since 2012 until the present.
- The abstraction from the Salalah wellfield was reduced by more than 60% in 2020 as reverse osmosis technology facility started to operate concurrently producing 25.2 Mm3/yr of water since the year 2013.
- It has been found that the direct injection method conducted along the eastern and western edges of the Salalah coastal aquifer was found less successful as compared to the injection procedure conducted in the middle of the injection boreholes of the aquifer.
- Those manifestations were attributed to the slow movement of underflow recharges in the edges of the aquifer along with the fast movement of saline intrusion.
- The solute transport shows that TDS results decreased in the current transient scenario as compared with the predictive scenario during the same period.

Conclusion and Recommendations

- There was weak subsurface flow, this study recommends refraining from injection procedures, instead, allocating the rate of injection among other boreholes.
- Similar to the 2008 recommendation of the author, Garziz farm should be relocated since they are pumping 8 Mm3/yr from 13 wells for the cultivation of Rhodes Grass. Since 2012, 10 wells were closed in Garziz farm, which means only 3 wells remain pumping groundwater at almost approx. 2.26 Mm3/yr.
- The implication that 77% of the pumping rates were blocked from 2012 to the present would definitely be helpful to the coastal aquifer.
- The expansion of the STP also took place and the central STP currently (2020) treats more than 50000 m3/day effluents to a tertiary level, of which only 40% of MTEs outputs were used (2020) for artificial recharge.
- This study recommends reusing more than 80% of MTEs into injection bores. These processes can be considered as an effective integrated water resource management method for Salalah coastal aquifer.

Acknowledgments

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